EMCAL (WBS 1.4)

Yuichi Kubota (WBS 1.4)

Overview

- Introduction and overview of the BTeV EMCAL
- WBS 1.4 – EMCAL
  - Project requirements and descriptions
  - Project organization
  - Costs
  - Schedule
  - Milestones
  - Risk Assessment
  - Response to principal CD-1 recommendations
- Presentations prepared for the breakout sessions
  - Crystal acquisition
  - Crystal acceptance test
  - Calibration

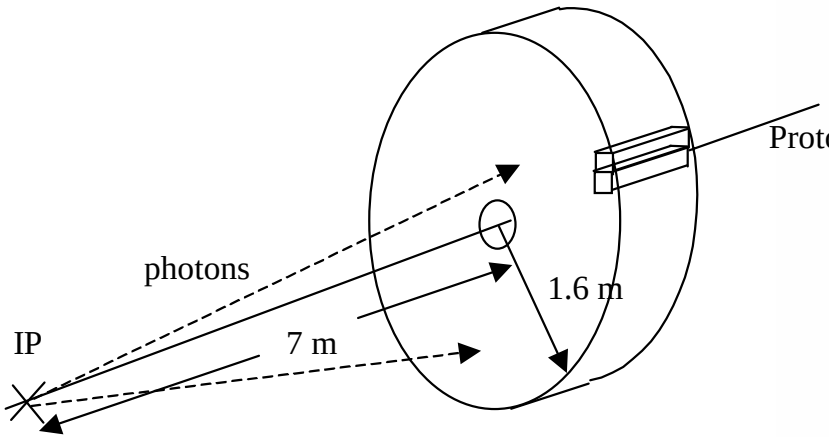
Introduction

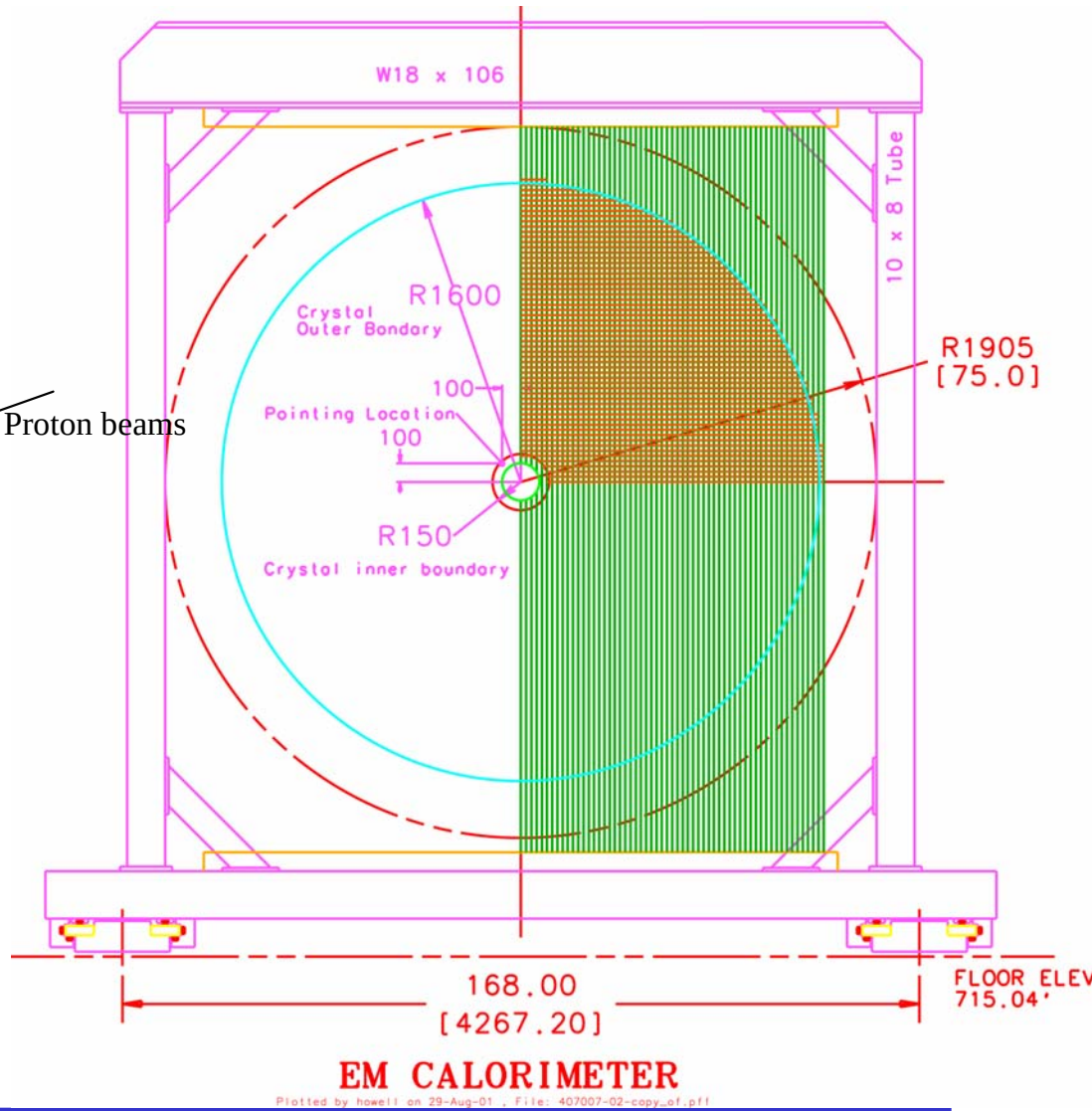
- The role of BTeV EMCAL is to reconstruct photons and help identify electrons with high resolution and efficiency in a high-rate (and high radiation) environment.
- Energy and position resolution goals (better than requirements) are

$$\frac{\sigma_E}{E} = \left(0.55 \oplus 1.8/\sqrt{E}\right)\ \% \text{ and}$$

$$\sigma_x = \left(0.2 \oplus 3/\sqrt{E}\right) \text{mm, where } E \text{ is in GeV.}$$

3 D view and Front view WBS 1.4



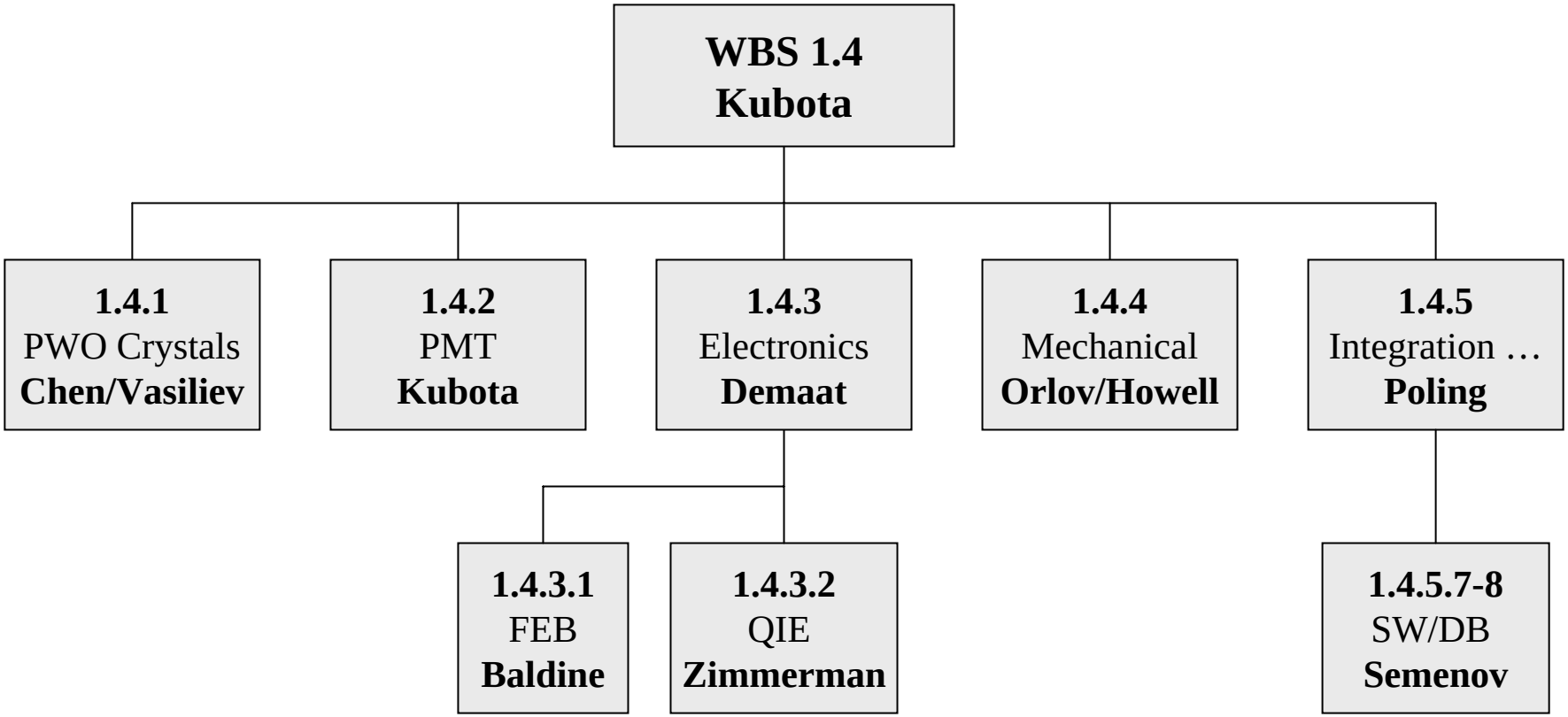


Major components WBS 1.4

- Lead-Tungstate ($PbWO_4$ or PWO) scintillation crystals are used to detect photons.
  - Why Lead Tungstate Crystals
    - Excellent energy and spatial resolution.
    - Fast – no tail in the next crossing
    - Compact – minimum shower overlap
    - Rad hard – survive hadron machine environment
- Photomultiplier tubes (PMT) are used to detect scintillation light (no *B* field)
- Custom ASIC – QIE – is used to digitize signal with 0.6% step size in 8 ranges and pseudo log-scale ADC (FNAL has much experience with QIE – KTeV, CDF, CMS, MINOS)

Organization WBS 1.4

Base cost: $15.4M (Material: $13.2M, Labor: $2.2M)



R&D results

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- Resolution
- Radiation hardness of PWO (and other components)
- Calibration scheme
- Light calibration system – 0.2%
- Mechanical structure
- MC –
  - electron rates for calibration;
  - radiation levels
  - Feasibility of muon calibration
  - Effect of 1% resolution
- Source-based measurements of radiation tolerance of crystal for QA
- QIE: design is progressing & expect the prototype submission this year
- Develop front-end boards (FEB) to utilize QIE prototype @FNAL testbeam
- Radiation hardness of optical glue – 10 qualify
- Radiation hardness of wrapping materials – Tyvek, Teflon and aluminized Myler all work

Mechanical Design and Prototype WBS 1.4

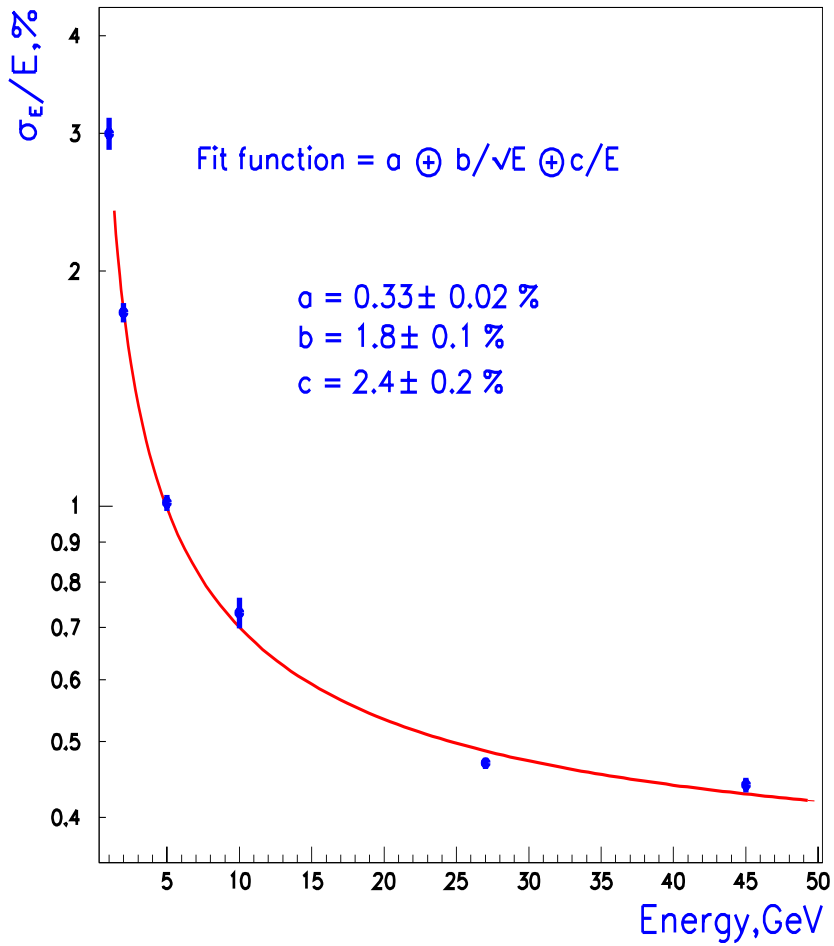
- Gave up CMS-endcap design (carbon fiber cells) – expensive, not needed.

Successful

Good for cost & estimates

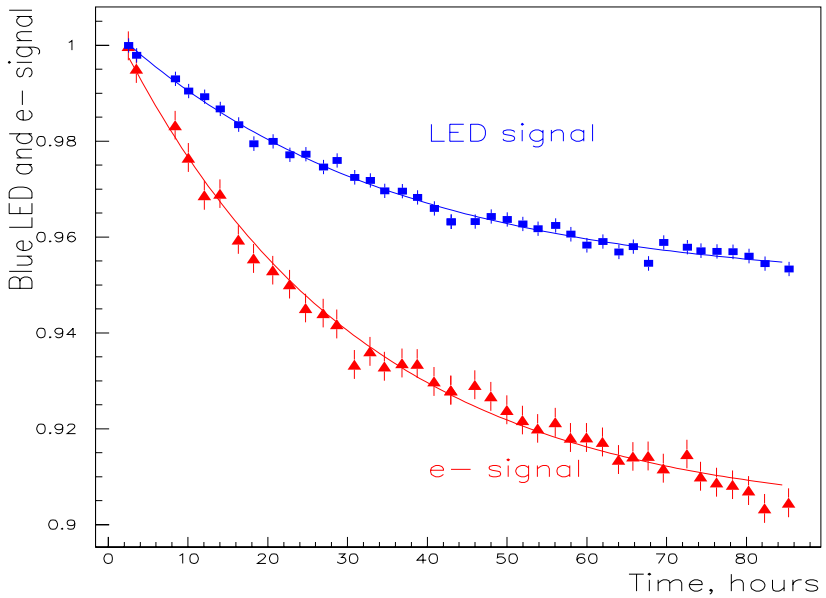
Test beam Results: Energy Resolution

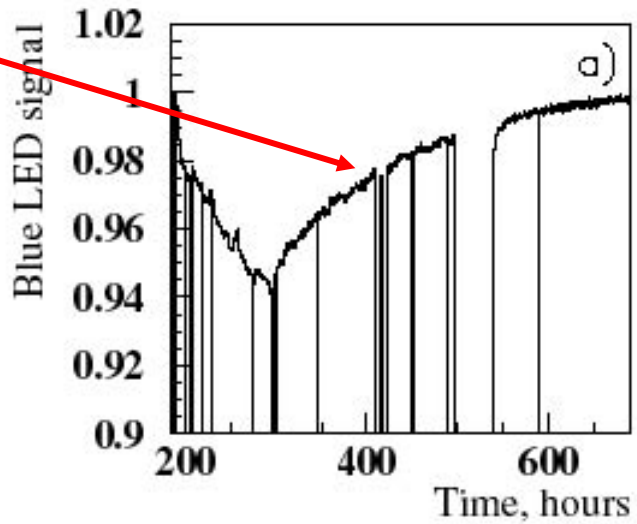
- Agreement with our Monte Carlo prediction
  - constant term (a) (uniformity and shower leakage), and
  - stochastic term (b) (shower leakage and photon stat. [~ 5 p.e./MeV])
  - "noise" term (c) is actually due to momentum measurement error of electron beam arising from multiple scattering – note: under constant deflection, not constant magnetic field.



Light loss from Radiation

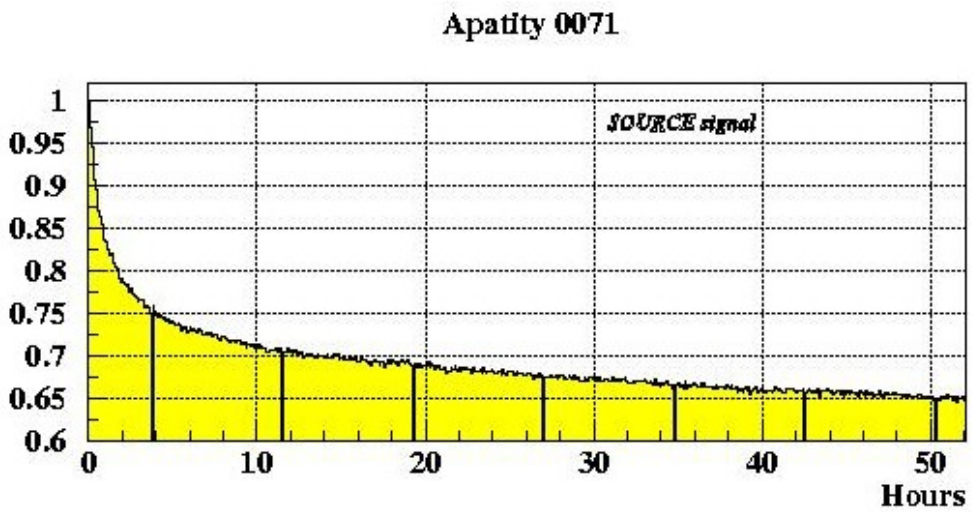
- Light loss (at dose rate of 15 rad/h) is exponential and saturates.
- Confirmation of damage recovery mechanism
- Time constant of loss is ~30 hours.

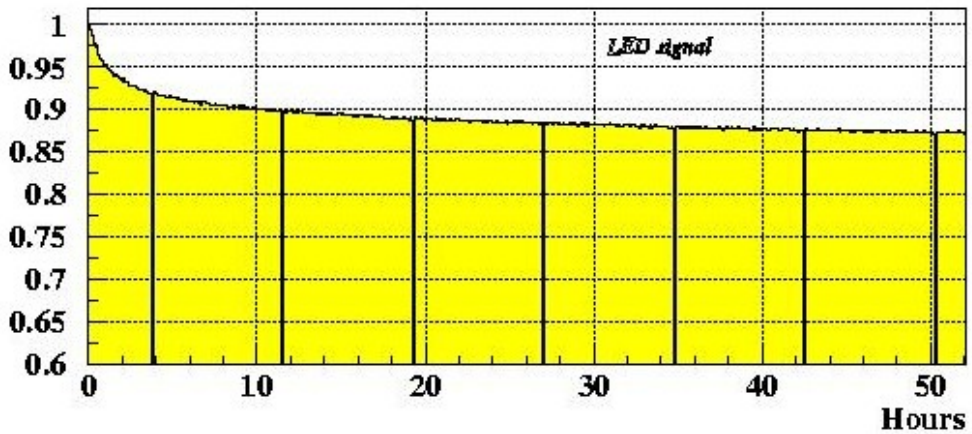




QA of crystals for radiation hardness WBS1.4

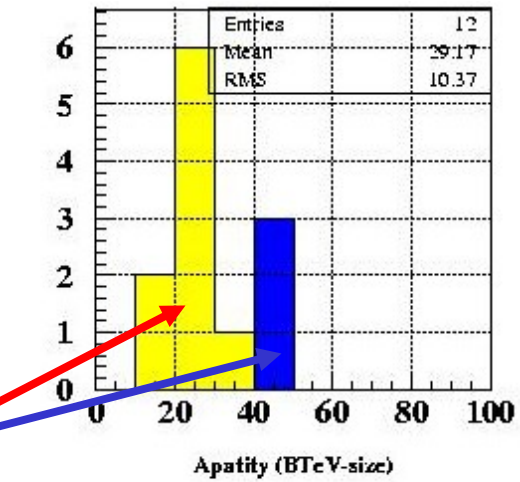
- We will test crystals for radiation tolerance using Cs source.
- Irradiate crystals at 100 rad/h for 20 hours and see how much light is lost.
- Monitor with both source (DC current) and LED pulser.

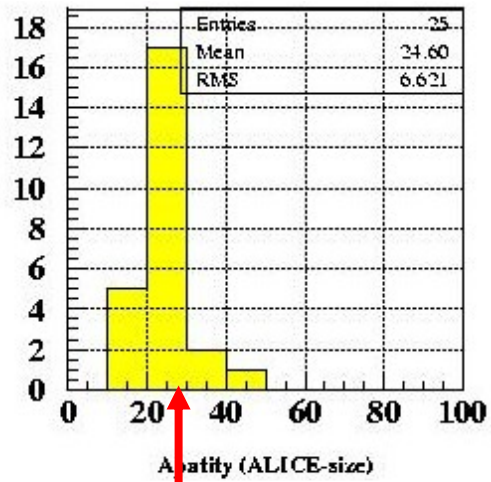


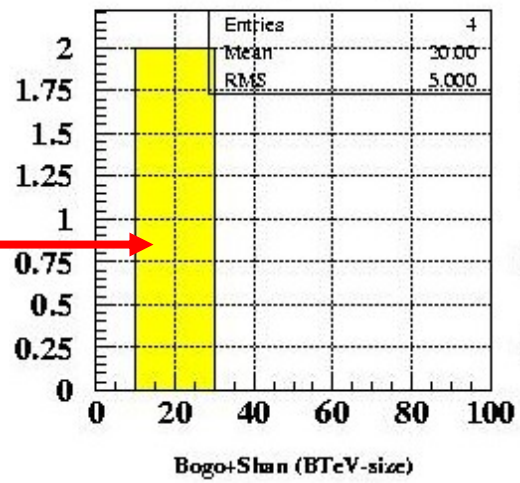


Apatity crystals WBS1.4

- Using the previous facility, we measured the radiation hardness of Apatity crystals.
- Earlier crystals (same growing method as ALICE crystals) were not very good.
- Newer ones are comparable to Bogoroditsk/SIC crystals.



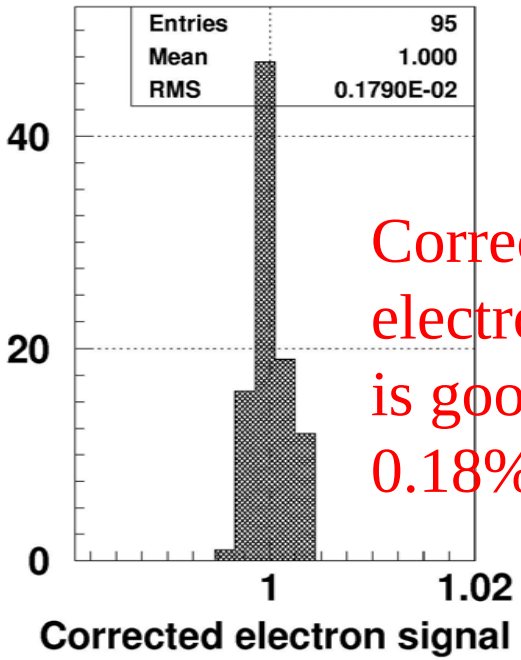




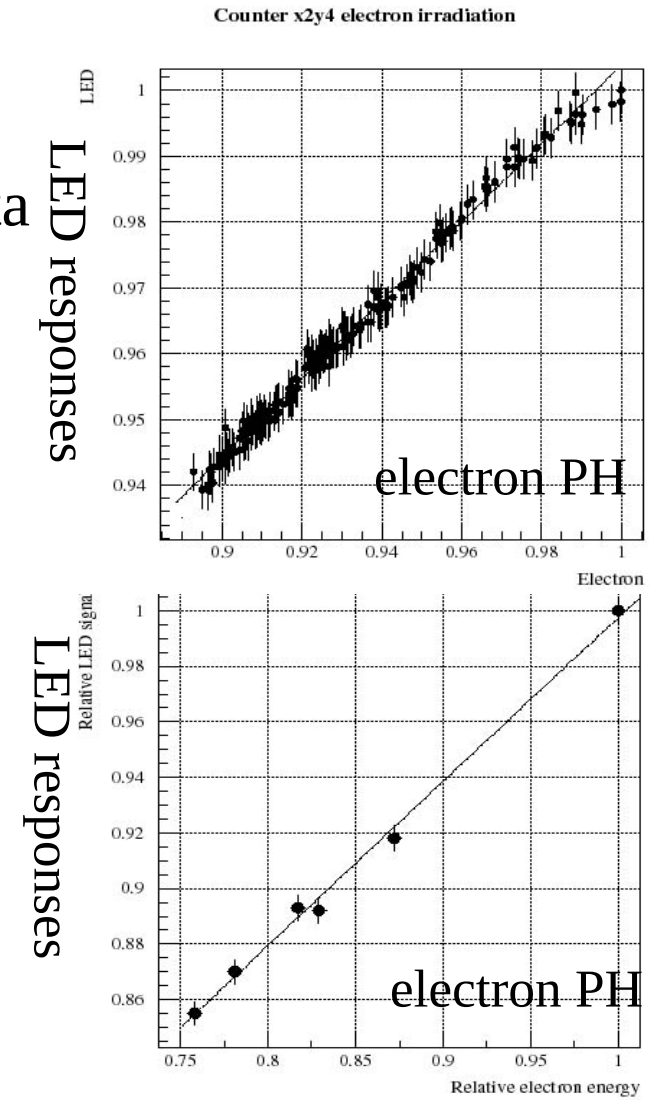
ALICE-size crystals were fine w/o growing-method modifications!

Correlation: LED *vs* Electrons

- The ratio of their changes (or slope of the graphs) is important to know.
- Then we can correct the particle data using LED data.



Corrected electron PH is good to 0.18%!

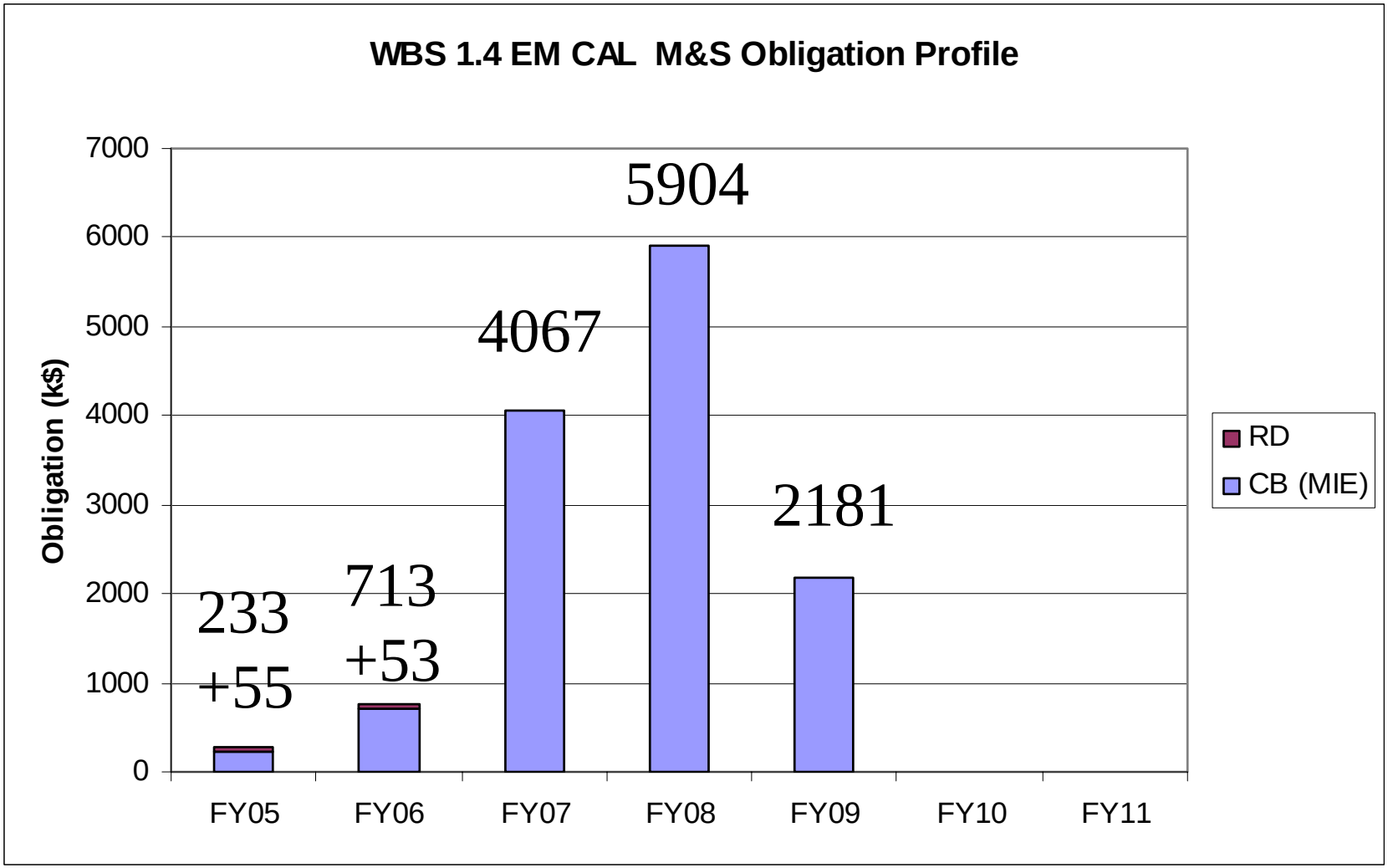


Construction Cost WBS 1.4

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY10	Total FY05-10
1.4.1	Detector - PWO Crystals	9,116,109	40	30	133,226	671,812	1,993,349	5,498,691	4,426,707	0	12,723,785
1.4.2	Detectors - PMT's bases	2,290,653	28	24	0	202,510	1,332,003	1,345,432	40,604	0	2,920,548
1.4.3	EMCAL Electronics and Associated Infrastructure	2,303,631	32	29	218,371	709,793	1,628,574	466,041	0	0	3,022,778
1.4.4	Mech Air and Temperature ctrl Systems	822,444	20	24	0	182,959	428,795	345,026	52,925	0	1,009,705
1.4.5	Integration and Testing	574,866	26	32	83,262	557,804	102,948	8,933	0	0	752,946
1.4.6	EM Calorimeter Detector Subproject Management	258,999	38	25	43,353	77,248	73,697	107,282	30,471	0	332,052
1.4	file_14S_091904	15,366,701	36	28	478,212	2,402,126	5,559,366	7,771,404	4,550,707	0	20,761,815

3M (4M) increase due to Russian crystals

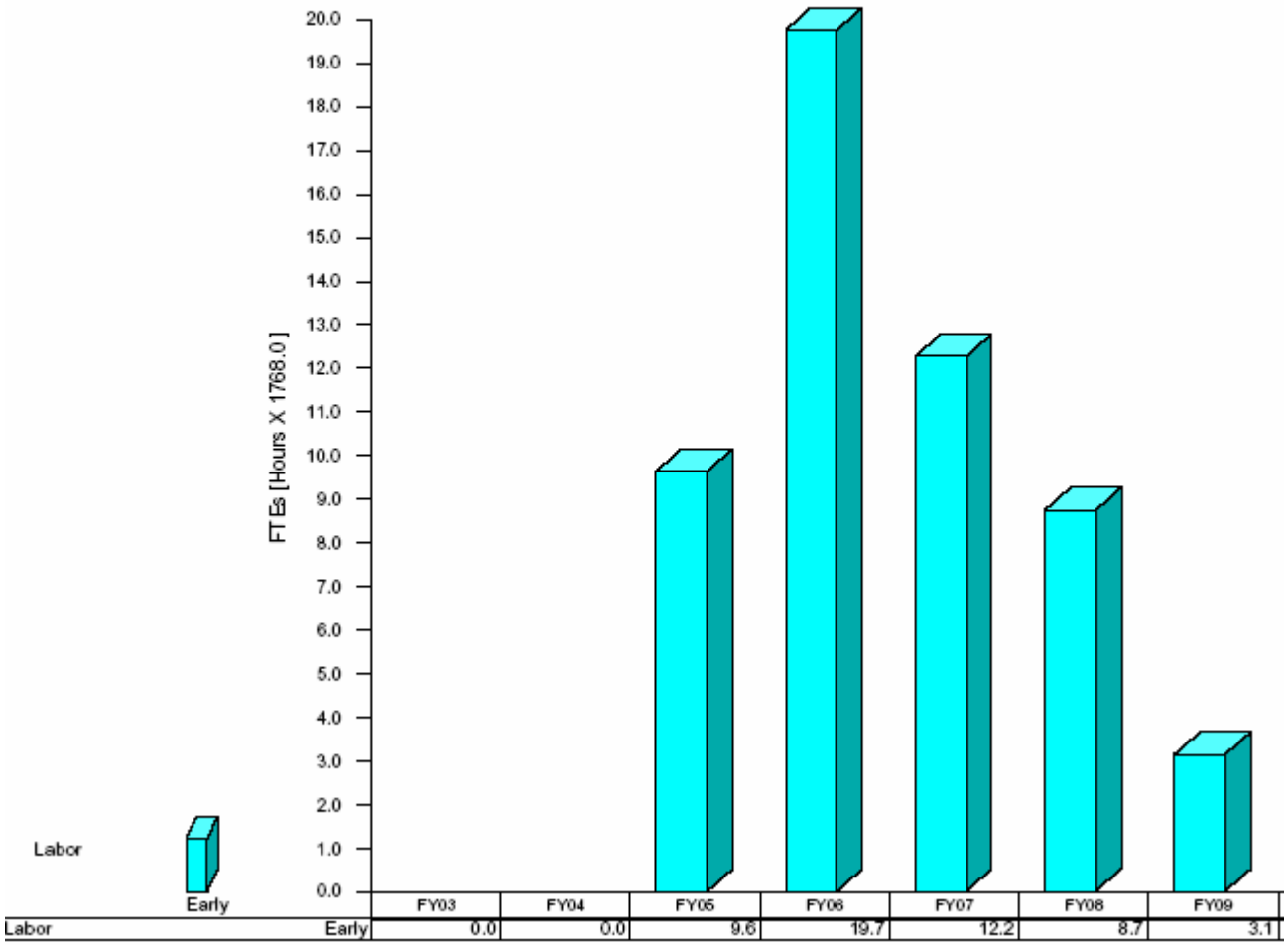
M&S Obligation Profile by Fiscal Year WBS 1.4



Labor Profile by Fiscal Year WBS 1.4

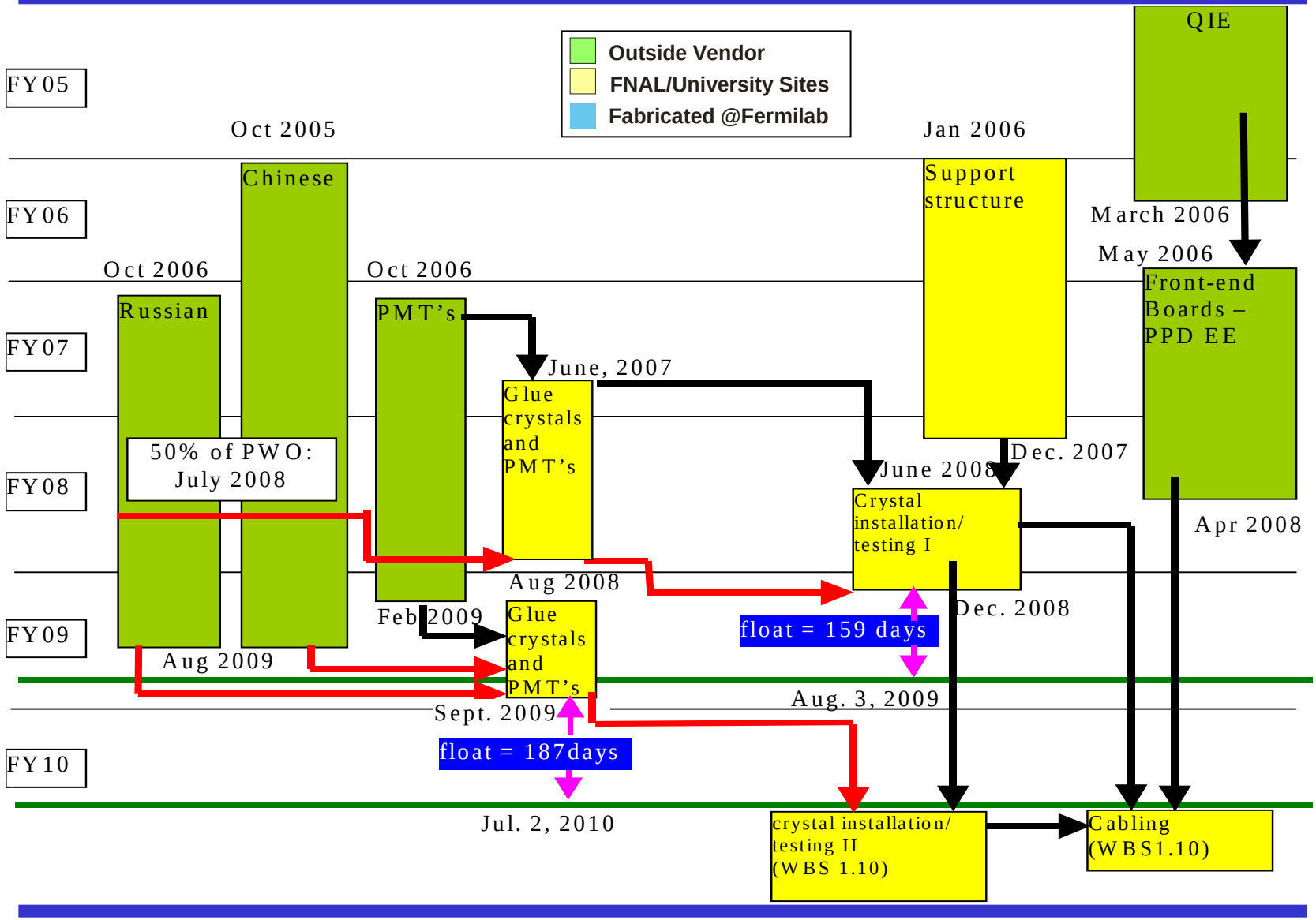
Filter: C1 = CONSTRUCTION
C5 = No Filter

BTeV - WBS 1.4 EM Calorimeter
Construction Labor Time Profile (FTEs) by Fiscal Year
All Labor



Labor		FY03	FY04	FY05	FY06	FY07	FY08	FY09
	Early	0.0	0.0	9.6	19.7	12.2	8.7	3.1

Project Flow



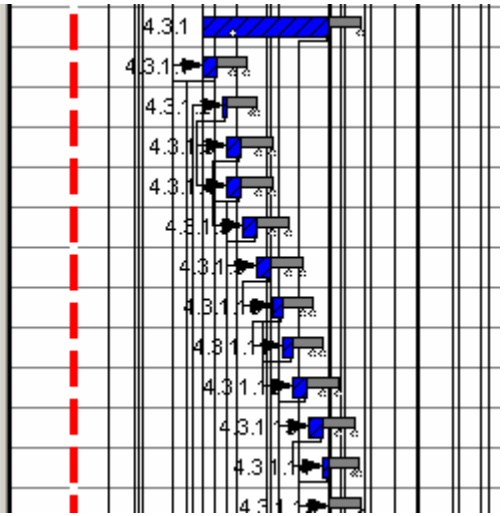
Key Milestones

Activity ID	Description	Date
7.2.4.1	PO Awarded: 1st EMCAL Crystals	4Oct05
7.2.3.1	PO Awarded: Production QIE Chips	16Sep05
7.2.4.4	QIE Packaged Parts Tested	08Mar06
7.2.3.2	20% of PWOCrystals Accepted	07Mar08
7.2.4.3	ADC Card Checkout Completed	11Apr08
7.2.3.4	EMCAL Support Structure Assembled	9Jun08
7.2.3.3	75% of PWO Crystals Accepted	21Jul09
7.2.4.2	EMCAL Crystal Procurement Completed	19Mar10
7.2.4.6	Assembly of EMCAL Completed	15Sep10

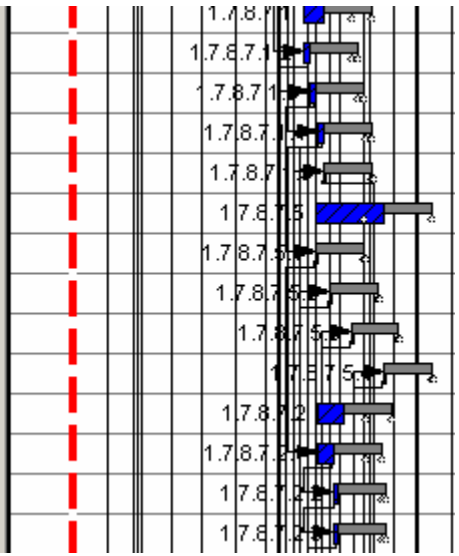
Critical Path Activities

WBS 1.4

4.3.1	Crystal Temp Ctrl System Engineering Design Phase	Subproject	505d	123d	
4.3.1.1	Est Reqmts for Crystal Temp Control Syst	ASAP	60d	123d	
4.3.1.2	Lev4Rvw: Reqmts for Temp Control Syst	ASAP	20d	123d	
4.3.1.3	Research Thermal Insulation options	ASAP	60d	123d	
4.3.1.4	Analyze Heat/Mass Balance & Gas Flow Distribution.	ASAP	60d	123d	
4.3.1.5	Dev process flow diagram	ASAP	60d	123d	
4.3.1.9	Perf analysis for chiller & blower sizing	ASAP	60d	123d	
4.3.1.10	Specify & select chillers & blowers	ASAP	40d	123d	
4.3.1.11	Specify & select Instrus & controls	ASAP	40d	123d	
4.3.1.12	Des/Prep Dwgs for enclosure insulation/containment	ASAP	60d	123d	
4.3.1.13	Compl Dwgs for piping & ductwork	ASAP	60d	123d	
4.3.1.14	Lev5Rvw: Crystal Temp Control Syst Des Rvw	ASAP	20d	123d	
4.3.1.15	Lev4Rvw: Conduct Crystal Temp Ctrl Syst Des Rvw	ASAP	5d	123d	



1.7.8.7.1.2	Wait 30 days for 1st sub-batch to be made	ASAP	30d	187d
1.7.8.7.1.3	Vendor A 2nd 10% of PWO crystals	ASAP	20d	187d
1.7.8.7.1.4	Perf Accept Test of 2nd 10% of A PWO	ASAP	20d	187d
1.7.8.7.1.5	T5M: 2nd 10% PWO fr A rece'ved & Tested	Finish Milestor	0	187d
1.7.8.7.5	Schedule contingencies btwn at 20%	Subproject	265d	187d
1.7.8.7.5.1	SC: production - at 20% of PWO procurement	ASAP	0	187d
1.7.8.7.5.2	SC: testing - at 20% of PWO procurement	ASAP	0	187d
1.7.8.7.5.3	SC: sample test - at 20% of PWO procurement	ASAP	0	187d
1.7.8.7.5.4	SC: overall - at 20% of PWO procurement	ASAP	0	187d
1.7.8.7.2	Vendor A 2nd 10% - MINN	Subproject	100d	187d
1.7.8.7.2.1	Wait 60 days for some PWO to be tested/sent overse	ASAP	60d	187d
1.7.8.7.2.2	Vendor A 2nd 10% of PWO crystals to US	ASAP	20d	187d
1.7.8.7.2.3	clear customs for Vendor A 2nd 10% of PWO	ASAP	20d	187d



Critical Path Analysis (1) WBS 1.4

- Temperature control (TF = 123 days)
- Support structure & insertion of crystals (TF = 159 days)
- Russian crystal production (TF = 187 days)
  - We have to delay their production until funding is available in FY07.
- Chinese crystal production (TF = 189 days).
  - Start crystal production in FY06, but it has to be stretched due to its production capacity and funding availability.
- PMT bases (TF = 269 days)

Risk Analysis

WBS 1.4

Risk Event	Response/mitigation strategy
Cost of PWO crystals	• Keep three vendors (Shanghai, Bogoroditsk and Northern Crystals) viable • Keep up with their plans
Delay in PWO crystal production	• Same as above. • Partial installation of PMT/crystals is a viable option – the remaining crystals can be installed during relatively short access time.
Delay in PMT production	• w/ 4 potential vendors, some trade off between cost and schedule is possible. • Partial installation of PMT/crystals is a viable option.
Delay in the QIE production	• We are submitting prototype chips next month (Oct 9), and will move to production ASAP (Oct 2005).

CD-1 recommendations

- Explore ways to arrive at a schedule with comfortable float (>6 months) by working with BTeV Management and Installation & Integration group.
  - Staged installation of EMCAL is our answer to this recommendation. We now have a minimum of 187days business days (~ 9 months) of floats for crystals.
- Add an Installation Engineer to the project.
  - There will be an Integration Physicist in the Project Office.
- Add US collaborators
  - Yes, we are trying.

Summary for WBS 1.4

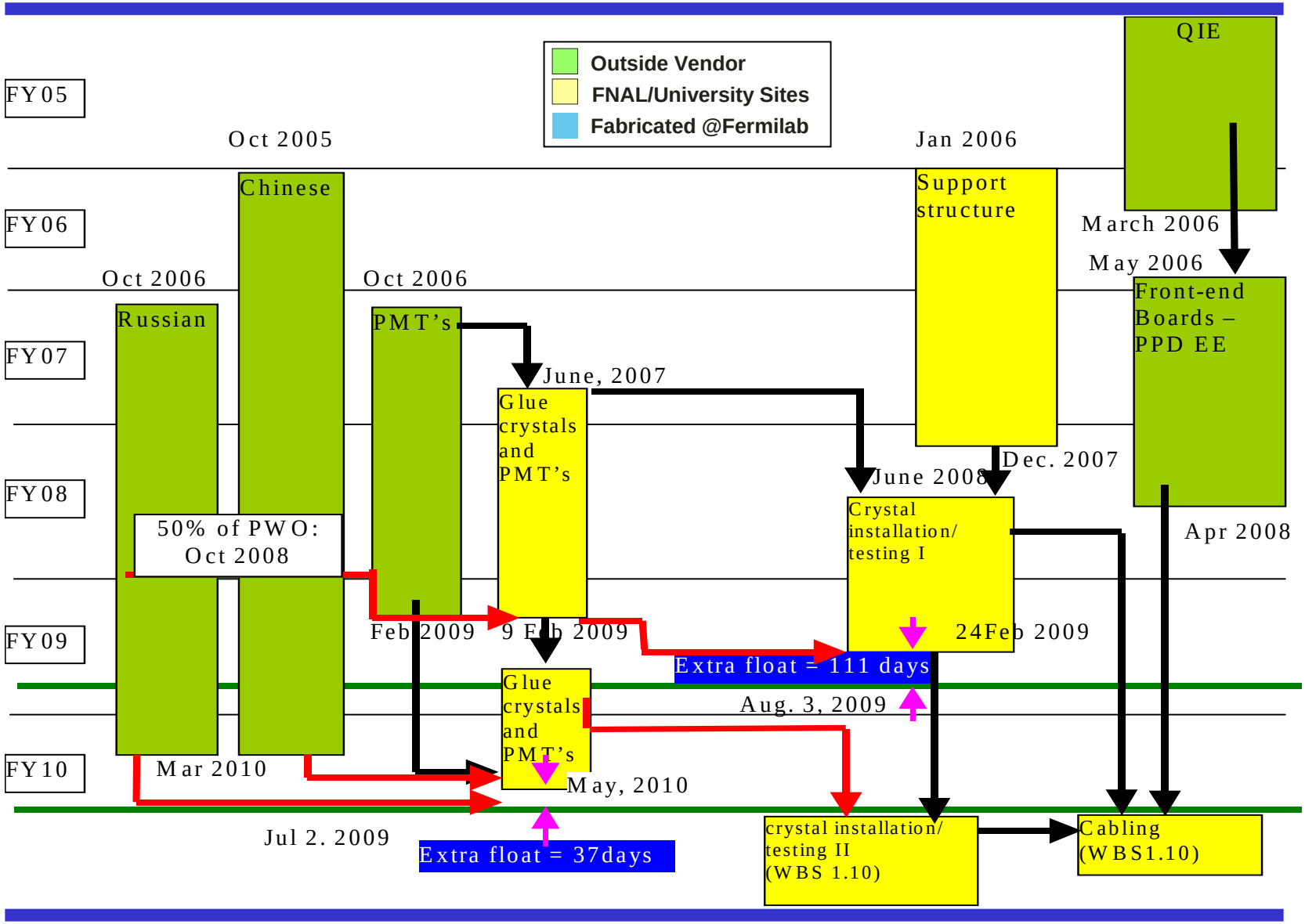
- No significant technical issues remain.
- Cost & schedule have been established bottoms-up using OpenPlan.
- Base $15.4M and 33% contingency for $20.8M total represent $3M increase in the base.
- Apatity crystals more fully qualified.
- Crystal acquisition floats increased to over 9 months due to staging – more forward funding from universities is being sought to speed up further
- In the worst case, commission with partial crystal installation is an option.

More information for WBS 1.4 is available in the breakout sessions.

- Irradiation studies w/ Cs source at IHEP – Alexandre Vasiliev
- Calibration – Alexandre Vasiliev
- Studies of possible scintillation mechanism damages – Alexandre Vasiliev

The End

Project Flow w/ schedule contingency



Responses to Temple 04 WBS 1.4

1. The collaboration should make every effort to accelerate the procurement of crystals either through forward funding or by qualifying 3 vendors.
   - ➢ We will certainly be making effort to secure forward funding to accelerate crystal acquisition.
   - ➢ Qualifying Apatity is done – Sasha's talk.
     - ALICE-size crystals worked very well.
     - full-size crystals (first 3) did not do as well
     - IHEP has evaluated 9 additional crystals with improved growing method and obtained results comparable to Bogoroditsk and SIC

2. More effort, including models and prototypes, should be applied to understanding the mechanical issues behind the calorimeter to ensure that the cable and fiber plant does not impede adequate airflow.
   - ➢ We are building a mock up of the entire crystal assembly, including HV, electronics and light fibers .

Responses to Temple 04 II

3. The thermal calculations should be repeated with a larger temperature variance in the C0 collision hall.

The older calculation can be re-interpreted to deal with situation when the C0 temperature varies more than 1 C. Our project engineer does not believe that the temperature variations will be more than 1 C, however. The reasons are:

1. The CDF hall temperature data suggest that temperature in the C0 hall will be very stable, much better than 1C, except during access time. Because of the thermal mass of EMCAL, short access will not effect its temperature.
2. After a long access time, when the hall temperature is much different from the regular running temperature, it will take some time for EMCAL to reach a stable temperature.
3. In case that C0 hall temperature swings much more than B0 hall, the existing analysis shows how additional isolation can be achieved by increasing the insulation or increasing the air flow So there is no need to re-do the calculation.
4. We will look at the tradeoffs of these changes when we do more detailed design of the environmental enclosure.